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# The role of stimulus and response generalization in a two choice reaction time task.

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# THE ROLE OF STIMULUS AND RESPONSE GENERALIZATION IN A TWO CHOICE REACTION TIME TASK

A Dissertation

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A Dissertion Presented

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Human beings do not passively perceive stimuli and then make an appropriate response, but when possible, try to anticipate what is going to happen so that they can be prepared for it. Certain cues may give them a basis for their anticipations, and can become associated with the different responses. If the cues and associated events of one task affect the responses in another, one can say that generalization has occurred. The present study is intended to investigate the possibility of generalization effects from choice reaction time (RT) tasks upon simple reaction times.

Simple Reaction Time.

A simple reaction time task is one in which subjects are confronted with only one stimulus and have one available response. When that one stimulus appears, the time between its onset and the subjects' reaction is defined as the reaction time. Most studies involving simple RT have investigated the effects of many different physical variables on RTs. However, Teichner (1954) only reports studies on one cognitive variable, set, in his review on simple RT experiments. Teichner presents studies showing that he hypothesizes that "RT will depend on the degree to which (the) S is ready to respond" (Teichner, 1954, page 136). One way of increasing the probability that a S is set for a forthcoming stimulus is to present a ready signal shortly before each stimulus. The presence of a ready signal 1.5 to 8 seconds before the stimulus yields faster RTs than the RTs in the absence of a ready signal, or if the ready signal is presented outside of that time range.

One other variable which might influence the subject's readiness to react is whether he is set to react to the stimulus, called a "sensory attitude" or whether he is concentrating on the reaction itself, a "muscular attitude". Teichner (1954) points out that while most studies find faster RTs with a muscular attitude, there have been no recent controlled studies to confirm this.

No further psychological variables are mentioned in the Teichner review. The simplicity of the simple RT paradigm seems to preclude the use of many of the 'traditional' variables. Choice RT, on the other hand, allows the testing of a variety of variables, and has shown itself sensitive to many of these.

Choice Reaction Time.

A choice RT experiment typically involves a set of stimuli, a set of responses, and the mapping of the stimuli onto the responses as specified in instructions given to a subject (S). In each trial, one of the possible stimuli appears, and the S makes the appropriate response as quickly as possible. The time between the onset of the stimulus and the initiation or completion of the response is the RT, and "is used as an indicant of the nature of processes (associative and others) in well established tasks...." (Smith, 1968, page 77).

Most choice RT experiments have investigated either the effects of event probability or the effects of the sequential structure of the events. In the first type of experiment, Hick (1952) found an orderly function relating choice RT to the number of equally probable stimuli; RT was proportional to $\log_2$ of the number of alternatives. Hyman (1953) also varied the number of stimulus alternatives, but within a set of stimuli, each stimuli did not necessarily occur with equal frequency. He found that RTs were faster to the most probable stimuli, and increased monotonically as the probability of a stimulus decreased.

Stimulus uncertainty, then, directly determines reaction times. When there is little stimulus uncertainty, the S is confronted with a highly predictable task. He would probably tend to anticipate the more likely stimulus most of the time, and the high frequency with which that stimulus occurs would reinforce his set for it, yielding faster RTs. However, when uncertainty is highest (all stimuli are equally probable) the S is in a less predictable situation. Thus, it seems likely that his expectancies of any one stimulus would be low. Therefore, he is less likely to be set for a stimulus which does occur, which is reflected in slower RTs.

The sequential structure of the stimuli is another factor found to affect event expectancies, as reflected in Ss' latencies, in choice RT experiments. In a typical experiment, the probabilities of one event, given which event occurred on the last trial, is varied. For example, the stimuli in a two choice task might be equally probable, but presented sequentially such that in one group an event on any trial would be repeated on the next trial 75% of the time, while in another group one event will be followed on the next trial by the opposite event 75% of the time. Experiments similar to this example have been run (Bertelson, 1961, 1965; Moss, Engel and Faberman, 1967; and Williams, 1966). Bertelson's experiments have shown that RTs to repeated stimuli are usually faster than RTs to alternated stimuli, which he calls the "repetition effect". For example, the Ss in one experiment (Bertelson, 1961) were confronted with two equally probable stimuli, but in each of the three groups, a stimulus was repeated on the next trial 75, 50 and 25% of the time, respectively. Crossed with this variable were two levels of response-stimulus interval. Under one condition, the next stimulus appeared 0.5 sec. after the release of the response key, while in the other group, this interval was only 0.05 sec. In the group with the equal number of repetitions and alternations, Bertelson found that the 0.05 sec. group showed significantly faster repetition RTs than alternation RTs, while in the 0.5 sec. condition, there was no difference. In 1965, Bertelson demonstrated that this effect was due more to the repetition of the response than to the repetition of the stimulus. The Ss in this experiment made only two responses to four stimuli, such that there were two stimuli for each response. In this way, a repetition response was made either to the repetition of the same stimulus or to an alternation of equivalent stimuli. The results showed that the repetition effect was primarily due to a repeat of the response, but there was also a slight effect due to a repetition of identical stimuli.

Conversely, Moss et. al. (1967) and Williams (1966) have found alternation RTs to be faster than repetition RTs, at longer inter-trial intervals (ITIs); an "alternation effect". Both of these studies contained two choice sequences of 50% repetitions, but the ITIs averaged from 12-15 sec. The Moss et. al. study also had groups with sequences of 25 and 75% repetitions as did Bertelson (1961), but only in the 75% repetition group were repetition RTs slightly faster than alternation RTs. The authors suggested that the increase in RT to alternated trials in the Bertelson studies could be due to the extra time needed to overcome the previously inhibited response. Possibly the longer ITIs give the Ss time to discharge this inhibition.

An alternate explanation concerns the Ss' strategies. If the Ss are making a convert prediction on each trial, they have less time to change it with the short ITIs, and still respond rapidly. They therefore might tend to stay with their prediction of the last trial, yielding faster RTs if that stimulus is repeated, and slower RTs if it is not. With longer ITIs, they have more time to make their decisions, and the negative recency effect, which is a tendency to alternate predictions found in probability learning (PL) studies, may occur.

Probability Learning.

Probability learning (PL) is a related area of investigation in psychology in which Ss predict which stimulus will occur on any one trial, instead of reacting to the occurrance of the stimulus. In the most common experimental design, each event has some fixed probability of being reinforced (indicated as correct) on every trial. After a prediction by the S, the correct event occurs and terminates the trial. The most frequently used dependant variable is the proportion of times each stimulus is predicted; latencies of the predictions can also be used. The primary difference between PL and choice RT, then, is that in PL, the Ss' response is probabilistic, while in choice RT, the response is deterministic. This difference may be a small one, though, because studies of the effects of such variables as stimulus probabilities and sequential probabilities on PL have been given results similar to those found in choice RT.

In numerous PL studies (cf. Estes, 1964), asymptotic predictions of the different stimuli are approximately equal to the frequency with which each stimulus occurs. This is known as probability matching. For example, a study by Myers, Gambino and Jones (1967) measured both the probability of predictions and response latencies in four groups of Ss in a two choice task. These four groups differed only in the probability of each event's occurrance. Within each of the groups, the probability of the more frequent event, $P(E_1)$ or $\pi$, equalled .6, .7, .8 or .9. Latencies were measured from the onset of the event light on Trial n, which gave feedback to the Ss, to the prediction on Trial n+1. Their results showed probability matching, with some over- and under-shooting at values of .7 and .8, and, across groups, latencies of $E_1$ predictions ($A_1$ responses) decreased as $\pi$ increased. This latter finding is similar to what is found in RT studies when stimulus probability is varied. However, latencies of making an $A_2$ response (prediction of an $E_2$) did not increase as $P(E_2)$ decreased. In fact, the latencies of $A_2$ responses, when $P(E_2)$ equalled .1, were faster than all of the other $A_2$ latencies. It seems that the Ss were not deciding upon which prediction to make only in the interval measured. Rather, the Ss may have been keeping track of the ratio of the more frequent prediction to the less frequent prediction. Making the less frequent response may then have been a part of their overall strategy, and they made it whenever they had not made one for some time.

The effects of the sequential structure of events has also been studies in PL studies. Jones and Myers (1966), in a two choice prediction experiment, varied the number of trials over which events were randomized (20 vs. 300 trials). In the randomization over short blocks (RSB) condition, there were fewer repetitions (runs) of the same event, and the length of a run was shorter. The opposite was true in the randomization over long blocks (RLB) condition. They found that the Ss in the RSB group showed marked negative recency, which is a decrease in response probability as run length increases, compared to the Ss in the RLB condition. Stated differently, the Ss in the groups with fewer and shorter runs alternated their predictions more than the Ss who saw more and longer runs. To test further this finding, Gambino and Myers (1967) varied both the mean length and variability of runs in a two choice PL experiment. They found that (1) more Ss predicted the runs would end too soon in the low mean run length group than in the group with the greater mean, (2) that as the variability increased, the Ss more frequently predicted that runs would continue, and (3) that repetition responses also increased variability, the number of long and short runs is greater, but the presence of the longer runs seems to have a greater effect. This is not in line with the Bertelson (1961) findings. The low mean, high variability of the Gambino and Myers study had runs of 2-7 events, while Bertelson's 50% repetition group had runs of length 1 through 7. However, the distribution of runs of each length in the former experiment was rectangular, with ten or each run length per block of 60 trials, whereas the distribution of runs in the Bertelson study was probably closer to an expotential distribution, with many short runs, and few long runs.

The mean run length and the variability of run lengths in the Bertelson study were therefore low, and the results from the PL experiments would have predicted that the Ss would have been alternating their expectancies and should have been faster on alternation RTs than on repetition RTs. These results, in combination with Bertelson's (1965) finding that response repetition contributes more heavily to the repetition effect, increases credulance to Moss et. als. (1967) hypothesis that short ITIs do not give the Ss enough time to 'disinhibit' the previously inhibited nonresponses. The very short ITIs, then, seem to be the cause of the "repetition effect".

Generalization Studies In Probability Learning.

In many learning situations, the S's expectancies about the outcome may be based, in part, upon cues provided for him. For example, a rat in a maze may have learned that when the runway is colored black, food will most likely be found in the right hand goal box. And, if the runway is white, food will probably be on the left. In this situation, then, the rat may change his expectancies of where food is to be found as a function of the color of the runway. The color serves as a discriminative cue as to which set of expectancies is appropriate. The effect of a discriminative cue on probability learning has been studied in several experiments.

One of the earlier PL experiments using a discriminative cue was that of Popper and Atkinson (1958). In this study, the Ss were asked to predict if the letter "A" or the letter "B" was "correct" on each trial. Preceeding the Ss' predictions, the experimenter (E) read aloud one of two nonsense syllables. The syllables served as cues; on $T_1$ trials, one letter was correct (occurred) 85% of the time, and the other 15%--$P(E_1|T_1) = .85 = \pi_1$ and $P(E_2|T_1) = .15 = 1-\pi_1$. The probability of one letter being correct on $T_2$ trials varied among groups. For each of five groups, $P(E_1|T_2) = .15, .30, .50, .70$ or $.85$. The probability of each type of trial ($T_1$ v.s. $T_2$), $\beta$, was constant at .50 across all groups.

The results showed that the Ss' expectancies did change as a function of which discriminative cue was given. Probability matching occurred, as expected, when $\pi_2$, or $P(E_1|T_2)$, equalled .15 or .85, with $P(A_1|T_1)$, or the probability or predicting an $E_1$ on a $T_1$ trial, approximately equalling .85. The Ss in the $\pi_2$ = .3, .5, and .7 groups did not probability match, however, on $T_1$ trials, and $P(A_1 | T_1)$ was significantly less than .85, i.e., the Ss undershot. This effect was most prominent at $\pi_2 = .5$. These results have been replicated in more recent PL research, e.g., Myers and Cruse (1967), Massaro, Halpern and Moore (1967) and Schnorr (1968), and seem to show that Ss can develop expectancies in parallel, but these expectancies are not independent of each other.

The best explanation for this effect would seem to involve generalization from $T_2$ trials. At $\pi_2 = .5$, the Ss' uncertainty as to the correct response is highest. Their predictions, if the sequences of events is random, are reinforced only about 50% of the time, lower than those of any group. It could be said that the Ss have no 'best' response and, hopefully, are unbiased in their predictions of either event. This may generalize to $T_1$ trials and the Ss are less prone to make $A_1$ predictions. The Ss may have given up trying to accurately predict on $T_2$ trials, which in turn, affects their expectancies on $T_1$ trials. The above PL studies show this generalization affecting expectancies, as measured by overt predictions. Therefore, if this same generalization is found in a choice RT experiment, one could argue that the Ss were making covert predictions, or at least had developed certain expectancies.

The present study is a two choice discriminative RT study, with $T_1$ trials, simple RT trials, and $T_2$ trials choice RT trials. On $T_1$ trials, the cue is the onset of one light, while on $T_2$ trials, both lights go on. This type of cue is used to prevent an effect found by Schnorr (1968) and in a pilot study by the present author. The Ss in these experiments tended to associate one response with the unreliable cue ($T_2$) because of the 'proven' association of a response to the opposite side with the reliable cue ($T_1$). This association was more noticeable when the choice events were equally probable, with the event on the opposite side of the event associated with a $T_1$ being predicted more often, or reacted to faster. The probability of the different events on $T_2$ trials ($\pi_2$)' is varied among the groups ($\pi_2$ = .2, .5 or .8).

The main point of investigation concerns the generalization from $T_2$ trials upon $T_1$ trials. If this generalization is found, then RTs on $T_1$ trials should be an inverted V-shaped function of $\pi_2$, with the slowest RTs on $T_1$ trials found when $\pi_2$ = .5, and equally fast when $\pi_2$ = .2 or .8. Uhl (1964) posits that if one cue is 100% reliable, then no generalization will occur, based upon results from a PL experiment. However, Schnorr (1968) found the typical U-shaped-function even when $P(E_1 | T_1)$ was 1.0, a result obtained in a pilot study with RT as the dependant measure run by the author.

The second point to be looked for is the effect of sequential structure on RT. The response-stimulus interval in this experiment is about 2.5 sec., between the short values used by Bertelson (1961, 1965) and the longer values used by Moss et. al. (1967) and Williams (1966). This interval may still be too short and not give the Ss enough time, but as it is greater than the .5 second interval at which Bertelson found no repetition effect, we may find the alternation effect found by the other authors.

## M E T H O D

Subjects. The subjects were 60 right-hand male undergraduates in summer school at the University of Massachusetts. They serve as part of the introductory psychology course requirement.

Apparatus. Each S sat at one of 2 partially separated booths, each containing an 11" x 11" response panel. The panel's front edge, nearer the S, was raised 2" from the surface of the booth and sloped upward to a height of 3" at the rear. The response buttons were arrayed in the shape of an inverted triangle, and the single button nearest the S served as the "home button". The home button was located on the midline of the panel and 6" from the edge nearest the S. The response buttons were at an angle of about 45 degrees from midline, and 2" (center to center) from the home button. These buttons were connected to microswitches beneath the panel, and a force of approximately 2 oz. and travel of 3/4" was necessary to activate the switches. The event lights, NE51Hs, covered by a white translucent cap, were at the same angle from the home button and 1" further from the response buttons.

The sequence of stimuli were punched on paper tape and controlled, through a Western Union tape reader, which light or lights appeared and which light went off. Timing during a trial was controlled by a Hunter Timer which was manually turned on at the beginning of each trial, and off at the end of each trial. The Ss' latencies were recorded from Hunter Klock Kounters. White noise of sufficient loudness to mask the sounds of switches, relays and the tape reader was presented through headphones.

Design and procedure. On 50% of the trials, a single light appeared. In one half of the groups, this light ($T_1$) appeared on one side only, the fixed cue position groups.

For the remaining groups, $T_1$ appeared randomly on either side (50% to each side). On the other 50% of the trials, both lights came on ($T_2$). Two sec. after the onset of either cue, one of the lights went off. The probability of one light going off given a $T_2$ ($\pi_2$) was varied, and three levels of $\pi_2$, viz .2, .5 and .8 were used. The combination of the three levels of $\pi_2$ with the two groupings of $T_1$ positional variability yielded 6 groups, each of which is designated by the variability of the $T_1$ position, fixed (F) or random (R), and the level of $\pi_2$. Assignment of the Ss was random within each group.

After being seated, the Ss were told that they were participating in a RT experiment, and either one or both of the lights could appear. After approximately 2 sec., one of the lights would go off. Their task was to push the button under the light that went off as quickly as possible. The instructions emphasized that they were to wait until the offset of a light before reacting, and to be as accurate as possible. The Ss began each trial with the index finger of their right hand on the home button, and only used this finger for responses.

There were 800 trials in all. Each S was run in two 1 hour sessions, 24 hours apart, with 400 trials per session. Events were randomized over blocks of 100 trials with the restriction that the first-order conditionals did not significantly differ ($\chi^2$ (15) was less than or equal to 7.261) from the expected first-order conditionals. One sequence was generated for each group, but by appropriate switching, the more frequent event appeared on the left side for half of the Ss in each group, and on the right for the rest. Onset of a trial was under control of the experimenter, as well inter-trial interval (ITI), which averaged 1.5 sec.

# RESULTS

Response latencies were collected to test the hypotheses that generalization from $T_2$ trials, the choice RT task, can affect latencies on $T_1$ trials, the simple RT task, and following the presentation of one stimulus, RTs on the next trial are faster to a different stimulus than to a repeated stimulus (Moss, Engel and Faberman, 1967; Williams, 1966), which has been called the alternation effect. In all tests, because of the non-normality of the distributions, the reciprocal of each RT, or the response speed, was used, and means were reconverted from this data for pictorial and tabular presentation.

Before analyses were started, three types of errors were considered, the first being mechanical failures. Out of a total of 48,000 trials, six trials were lost due to the failure of the clock to reset properly. Of the remaining trials, two other types of errors were present - error responses and anticipatory errors. There were 1622 error responses, i.e., missing the button or pressing the wrong button; an error rate of 3.40%. This type of error was primarily found on choice RT ($T_2$) trials. Table 1 contains the number and percent error responses per group. An analysis of variance, using Cue Position, level of $\pi_2$, Days, Blocks and Ss as variables, showed no significant effects of any variable or the number of errors per group.

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Insert Table 1 about here

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There were also 372 RTs which were classified as anticipatory responses. These were defined as RTs of less than 150 msec., and they occurred mostly on simple RT ($T_1$) trials. A breakdown of the number of percent of these errors per group is given in Table 2. Another analysis of variance, using the same independent variables as above,

TABLE I

Number and percent error responses as a function of $T_1$ cue position and $\pi_2$

| | $T_1$ Position | |
|---|---|---|
| $\pi_2$ | Fixed | Random |
| .2 | 248 (3.11%) | 231 (4.18%) |
| .5 | 264 (3.31%) | 252 (3.07%) |
| .8 | 256 (3.22%) | 271 (3.42%) |

was run with anticipatory errors as the dependant measure. The only significant main effect was that of cue position, $F(1,54) = 6.95$, $p < .025$, showing that those Ss with the variable $T_1$ cue were making more anticipatory errors than Ss in the fixed $T_1$ groups. However, a closer inspection of the data showed that the greater number of errors was attributable to only a few Ss. This apparent heterogeneity of variance was substantiated by a significant $F_{MAX}$, with $F_{MAX}(6,79) = 5.51$, $p < .01$. This detracts from any conclusions drawn about the effect of cue position on anticipatory errors.

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Insert Table 2 about here

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In the remaining analyses, no error RTs were used; instead, the mean RT for that subject, event and block of trials was.

Reaction time as a function of $\pi_2$. Figure 1 shows how simple and choice RT changed over the two days of practice.

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Insert Figure 1 about here

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Within each group, the lowest curve shows the simple RT trials, pooled across events in the groups where a $T_1$ was on both sides. The other two functions within each group show the RTs to the two choice events. RTs to all events generally decreased (got faster) with more practice, and this decrease seemed greater on Day 1 than Day 2. The effect of stimulus probability is apparent, on choice ($T_2$) trials, in those groups where $\pi_2 = .2$ or $.8$. The events with the higher probability of occurrance were faster than those events with the lower probability of occurrance. The ordering of these results are consistent with those of many previous experiments.

The difference between the two choice events in Group F-.2 are greater than in Group-.8, $t(14) = 6.86$, $p < .01$. The main

TABLE II

Number and percent anticipation responses as a function of $T_1$ cue position and $\pi_2$

| | $T_1$ Position | |
|---|---|---|
| $\pi_2$ | Fixed | Random |
| .2 | 29 (0.37%) | 86 (1.12%) |
| .5 | 25 (0.32%) | 119 (1.54%) |
| .8 | 47 (0.61%) | 66 (0.85%) |

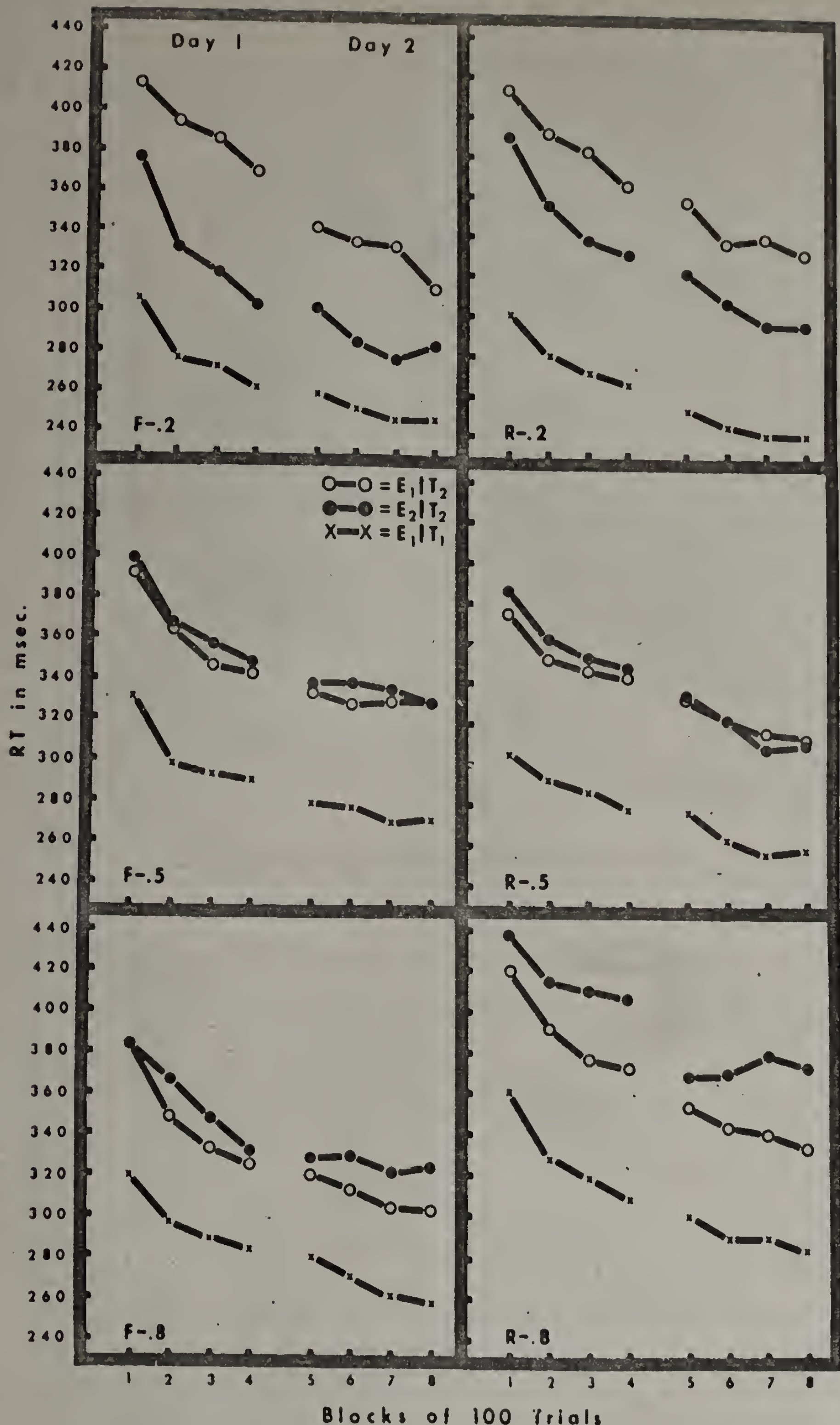


Figure 1. Group reaction times as a function of events, days and blocks.

difference between these groups was that in Group F-.2, the simple RT cue ($T_1$) was on the same side as the less frequent choice event, whereas in Group F-.8, $T_1$ was on the same side as the more frequent choice event. Therefore in the latter group, responses were made to one side 90% of the time, and in the former group, only 40% of the time.

The first analysis of variance was performed upon the mean speed on $T_1$ vs. $T_2$ trials for each S as a function of cue positional bias, level on $\pi_2$, days and blocks of 100 trials. The summary of this analysis is in Table 3. Response speed was directly related to $\pi_2$, $F(2,54) = 4.74$, $p < .05$, and increased over days, $F(1,54) = 182.60$, $p < .01$,

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Insert Table 3 about here

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and blocks within days, $F(3,162) = 111.65$, $p < .01$. More of the increase in speed occurred on Day 1 as compared to Day 2 and is reflected by the Days x Blocks interaction, $F(3,162) = 17.22$, $p < .01$. Simple RT was also significantly faster than choice RT, $F(1,54) = 423.41$, $p < .01$, and the speeds on simple and choice trials differed as a function of $\pi_2$, $F(2,54) = 3.43$, $p < .05$.

Inspection of the mean RT as a function of $\pi_2$ revealed that overall RTs increased as $\pi_2$ increased; for $\pi_2 = .2$, .5 and .8 respectively, mean RT was 291, 310 and 319 msec. Looking at the mean RT as a function of $\pi_2$ and the $T_1$ positional bias showed that the groups with the random $T_1$ position contributed heavily to this increase in RT, for $\pi_2 = .2$, .5 and .8, respectively, mean RT in the random $T_1$ groups were 293, 304 and 337 msec, whereas in the fixed $T_1$ groups, these means were 288, 315 and 303 msec. Because of this, further analyses were carried out separating the groups with the fixed cue position from those with the random

TABLE III

Analysis of variance comparing simple vs. choice reaction time as a function of cue position, $\pi_2$, days and blocks

| Source of variance | | |
|---|---|---|
| Between Ss | | |
| Cue position (C) | 1 | 1.15 |
| $\pi_2$ | 2 | 4.74 * |
| C x | 2 | 2.37 |
| Ss/C x $\pi_2$ | 54 | (1.6748) |
| Within Ss | | |
| Days (D) | 1 | 182.60 ** |
| C x D | 1 | .39 |
| $\pi_2$ x D | 2 | 1.82 |
| C x $\pi_2$ x D | 2 | .04 |
| Ss x D/C x $\pi_2$ | 54 | (.1780) |
| Blocks (B) | 3 | 111.65 ** |
| C x B | 3 | .31 |
| $\pi_2$ x B | 6 | 1.26 |
| C x $\pi_2$ x B | 6 | .36 |
| Ss x B/C x $\pi_2$ | 162 | (.0373) |
| Simple vs. choice RT (R) | 1 | 423.41 ** |
| C x R | 1 | 2.64 |
| $\pi_2$ x R | 2 | 3.43 * |
| C x $\pi_2$ x R | 2 | 1.02 |
| Ss x R/C x $\pi_2$ | 54 | (.2251) |
| D x B | 3 | 17.22 ** |
| C x D x B | 3 | 1.54 |
| $\pi_2$ x D x B | 6 | .38 |
| C x $\pi_2$ x D x B | 6 | 1.09 |
| Ss x D x B/C x $\pi_2$ | 162 | (.0290) |
| D x R | 1 | 1.79 |
| C x D x R | 1 | .50 |
| $\pi_2$ x D x R | 2 | .40 |
| C x $\pi_2$ x D x R | 2 | 2.04 |
| Ss x D x R/C x $\pi_2$ | 54 | (.0323) |
| B x R | 3 | 1.65 |
| C x B x R | 3 | .32 |
| $\pi_2$ x B x R | 6 | 1.20 |
| C x $\pi_2$ x B x R | 6 | .33 |
| Ss x B x R/C x $\pi_2$ | 162 | (.0114) |
| D x B x R | 3 | .32 |
| C x D x B x R | 3 | 1.92 |
| $\pi_2$ x D x B x R | 6 | .38 |
| C x $\pi_2$ x D x B x R | 6 | .84 |
| Ss x D x B x R/C x $\pi_2$ | 162 | (.0118) |

* = $p < .05$
** = $p < .01$

cue position. The data of the last 200 trials was defined as asymptotic performance, because of the lack of significance of the blocks effect, $F(1,54) = 0.35$ for $T_1$ trials and 0.70 for $T_2$ trials, and used in subsequent analyses. Finally, because the effect of $T_2$ trials upon $T_1$ trials was of interest, further analyses were also separated for simple and choice trials.

The mean RTs of the last 200 trials for each event per group with the fixed $T_1$ position are presented in Figure 2a. Note that both simple ($T_1$) and choice ($T_2$) RTs when $\pi_2 = .5$

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Insert Figure 2 about here

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were slower than at the other two $\pi_2$ values. On $T_1$ trials, this was the expected generalization effect from $T_2$ trials, and on $T_2$ trials, probably the effect of total group uncertainty, with uncertainty greatest at $\pi_2 = .5$. An analysis of variance on the speed scores (Table 4) showed that only the changes in choice RT as $\pi_2$ changed were statistically significant, $F(2,27) = 18.90$, $p < .01$, which

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Insert Table 4 about here

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merely reflects the changes in RT as one event increased in probability and the other decreased.

Although the effect of $\pi_2$ upon $T_1$ trials was not significant, $F_{quadratic}\,(1,27) = 1.84$, $p > .05$, simple RT as $\pi_2 = .5$ was consistantly slower than at the other $\pi_2$ values over trials (Figure 3). Only in the fifth block of trials was simple RT at $\pi_2 = .5$ not the slowest. There, RT at $\pi_2 = .8$ was equally slow.

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Insert Figure 3 about here

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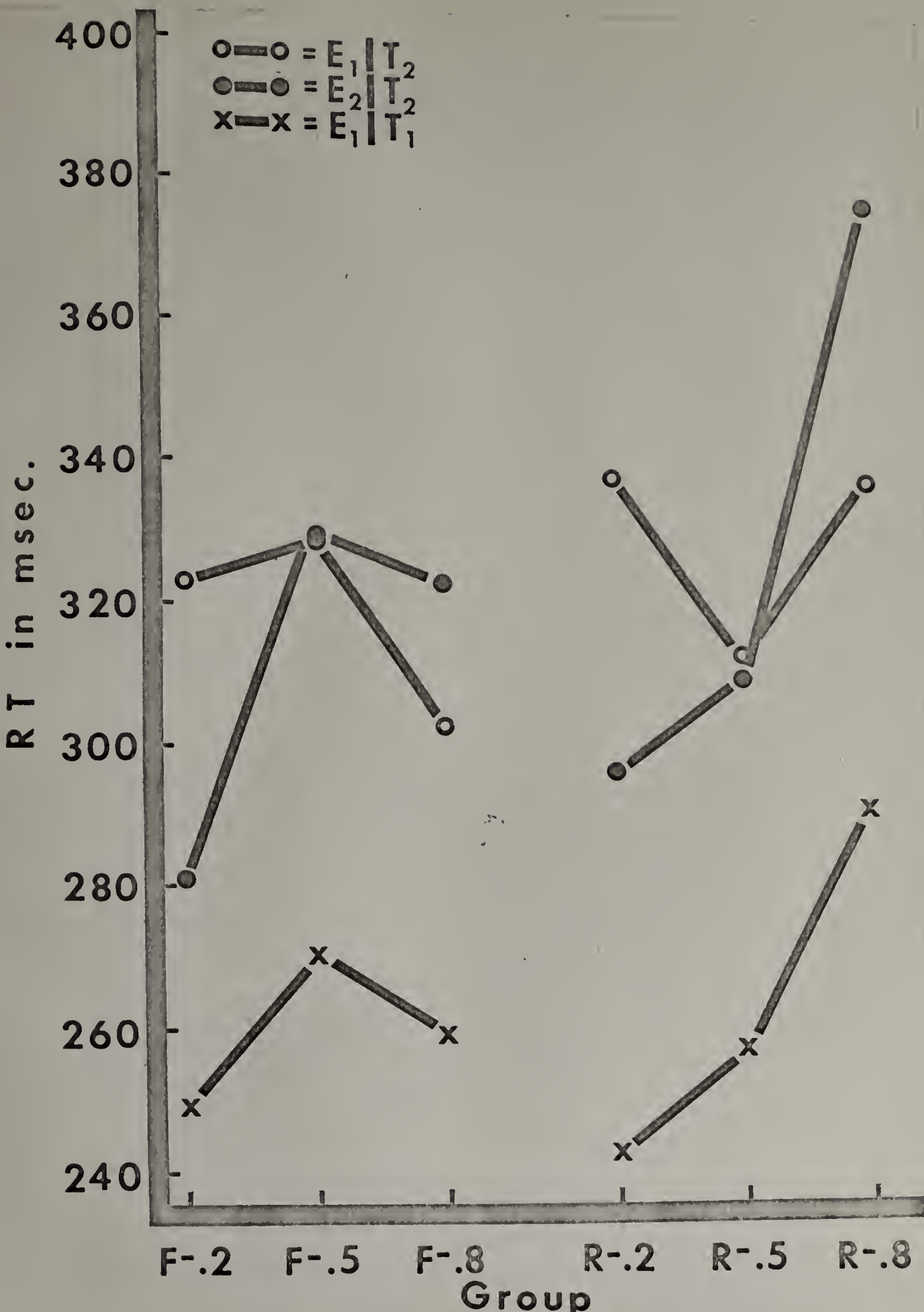


Figure 2. Mean reaction times for the last 200 trials per group as a function of events.

TABLE IV

Analysis of variance on mean response speed per subject for the last 200 trials as a function of $\pi_2$ and, on $T_2$ trials only, the response made for groups F-.2, F-.5 and F-.8

| Source variation | df | $T_1$ Trials | $T_2$ Trials |
|---|---|---|---|
| Between Ss | | | |
| $\pi_2$ | 2 | 1.25 | 1.55 |
| $Ss/\pi_2$ | 27 | (0.2430) | (0.3210) |
| Within Ss | | | |
| Response (R) | 1 | | 3.01 |
| $\pi_2$ X R | 2 | | 18.90 ** |
| $SsXR/\pi_2$ | 27 | | (0.0314) |

** = $p < .01$

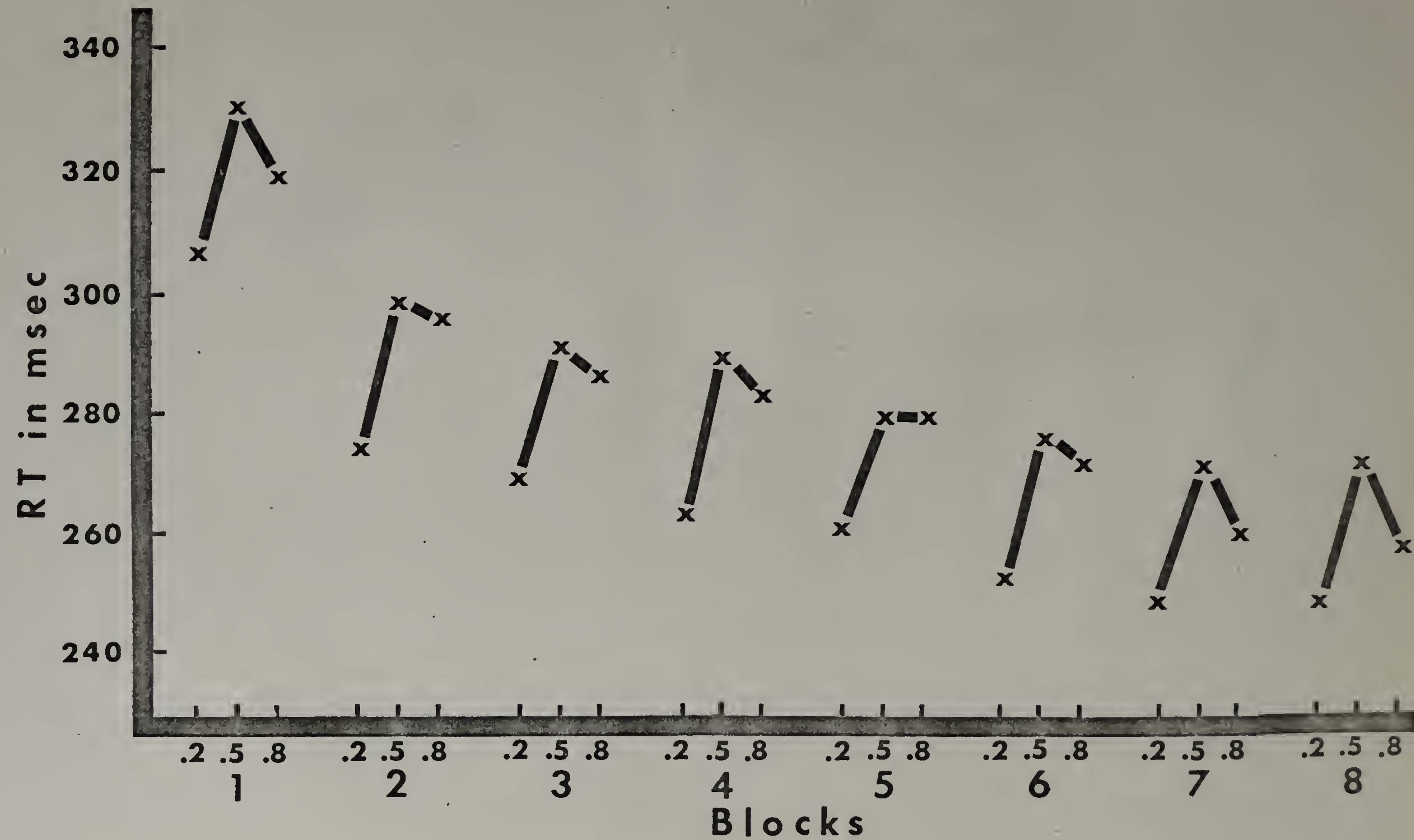


Figure 3. Mean simple reaction times across blocks of 100 trials for Fixed $T_1$ groups as a function of $\pi_2$.

In the groups with the variable $T_1$ position, where simple RTs were made to events on both the right and left sides, there was no significant differences attributable to which side, $\underline{z} = 1.21$, $p = .11$. Therefore, simple RTs were pooled disregarding which side they occurred upon, before other statistical analyses were done.

The analysis of variance performed upon the data of the groups with the random $T_1$ is summarized in Table 5. The mean RTs are presented in Figure 2b. The effect of $\pi_2$ on

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Insert Table 5 about here

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RT was significant for these groups, $F(2,27) = 10.86$ for $T_1$ trials and $F(2,27) = 7.75$ for $T_2$ trials, both $p < .01$. Looking at the mean RTs per event, we see that simple RTs increased as $\pi_2$ increased, $F_{linear}(1,27) = 21.53$, $p < .01$. This overall trend was also significant on choice RT trials, $F_{linear}(1,27) = 5.47$, $p < .05$. The significance, on $T_2$ trials, of the $\pi_2$ x R interaction, $F(2,27) = 24.41$, $p < .01$, again reflects changes in RT as the probability of the events changed. The large difference between Group R-.2 and Group R-.8 was unexpected, as those groups were essentially identical, differing only in the sequence in which the various events were presented, and the subjects within each group.

Because of this finding, further analyses were done comparing, within each level of $\pi_2$, the effect of Fixed vs. Random $T_1$ position. Only at $\pi_2 = .8$ was there a significant difference between groups $t(1998) = 12.40$, $p < .01$ for $T_1$ trials, with the average simple RT in Group R-.8 slower than in Group F-.8, and on $T_2$ trials, with the mean choice RT in Group R-.8 again slower, $t(1998) = 17.61$, $p < .01$. The effect of $\pi_2$, then, at $\pi_2 = .2$ and .5 was not affected by

TABLE V

Analysis of variance on mean response speed per subject for the last 200 trials as a function of $\pi_2$ and, on $T_2$ trials only, the response made for groups R-.8, R-.5 and R-.2.

| Source of variation | df | $T_1$ Trials | $T_2$ Trials |
|---|---|---|---|
| Between Ss | | | |
| $\pi_2$ | 2 | 10.86 ** | 7.75 ** |
| $Ss/\pi_2$ | 27 | (0.1032) | (0.1219) |
| Within Ss | | | |
| Response (R) | 1 | | 1.06 |
| $\pi_2 \times R$ | 2 | | 24.41 ** |
| $Ss \times R/\pi_2$ | 27 | | (0.0248) |

** = $p < .01$

the variability, or lack of variability, of the $T_1$ position. Group R-.8 seems to be at variance with Group F-.8 and previous findings. Had the Ss in Group R-.8 responded similarily to those in Group R-.2, the inverted V-shaped effect would have been seen on simple RT trials.

Also, RTs to choice events with a probability of .2 would have been slower than RTs to choice events with a probability of .5. This was found, comparing Group R-.2 with Group R-.5, but was not found in the groups with the fixed $T_1$ position. Based upon the results of Groups R-.2 and R-.5, it appears that the choice events in the "F" groups were affected by the fixed simple RT cue ($T_1$). With a random $T_1$, the relationship between the probability of a choice event and RTs to that event conforms to the data of past studies.

Sequential effects. Because of the combination of simple and choice RT trials, a further subdivision of the same stimulus vs. different stimulus used in previous experiments was possible. Where Trial n is a simple RT trial, and Trial n-1 was also, and on the same side, this is a repetition of context (trial type) and response. Or, if Trial n-1 was a simple RT on the other side, this would be an alternation of response only. When Trial n-1 was a choice task on the same side, this is a repeated response, but the stimulus is in a different context, a $T_1$ vs. a $T_2$ trial. And, when Trial n-1 was a choice RT event on the opposite side, there is both an alternation in context and response.

When Trial n is a $T_2$ (choice) trial, and the previous trial was a $T_1$ (simple) trial, there can be a repetition or alternation in responding, with the above noted difference in context. When two adjacent trials are both choice RT trials, we have the more classical repetition vs. alternation situation. To examine the effects of alternated context vs. alternated responding, the data of the last 200 trials was broken down as a function of the above classification (Table 6). The last two rows of the table contains the means across all

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Insert Table 6 about here

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groups. Looking at $T_1$ trials as a function of the previous trial for the overall means, simple RTs seems unaffected by the events on the preceeding trial. The differences between pairs, at the most less than 3 msec, were not meaningful. On choice RT trials, however, alternation RTs were faster than repetition RTs when the previous trial was a $T_1$ trial, $\underline{z} = 5.88$, $p < .01$, but repetition RTs were faster when the Ss were confronted with a choice task on the previous trial, $\underline{z} = 7.02$, $p < 0.01$. Although unexpected, the latter results are fairly consistant within each group, but the differences are smaller in Groups F-.5 and R-.5 where there were slightly most alternations than repetitions. Note that in the other groups that repetitions are, on the average, almost twice as prevalent as alternations. This bias may have affected the results.

TABLE VI

Mean reaction times in msec. and number of occurances on Trial _n_ as a function of the event on Trial _n-1_ for each group for the last 200 trials

| Group | Trial type | $T_1$ same side | | $T_1$ different side | | $T_2$ same side | | $T_2$ different side | |
|---|---|---|---|---|---|---|---|---|---|
| F-.2 | $T_1$ | 248.1 | (470) | | | 250.3 | (100) | 247.4 | (430) |
| | $T_2$ | 327.3 | ( 90) | 278.0 | (440) | 284.6 | (290) | 306.9 | (170) |
| F-.5 | $T_1$ | 270.0 | (510) | | | 274.0 | (240) | 272.0 | (250) |
| | $T_2$ | 331.5 | (230) | 328.7 | (250) | 330.4 | (230) | 336.3 | (280) |
| F-.8 | $T_1$ | 256.3 | (460) | | | 260.7 | (420) | 266.7 | (110) |
| | $T_2$ | 302.8 | (420) | 322.3 | (120) | 302.1 | (310) | 318.1 | (150) |
| R-.2 | $T_1$ | 237.9 | (260) | 240.7 | (250) | 244.3 | (270) | 240.2 | (210) |
| | $T_2$ | 306.1 | (230) | 304.1 | (260) | 301.9 | (350) | 310.0 | (160) |
| R-.5 | $T_1$ | 257.6 | (270) | 258.5 | (230) | 257.5 | (230) | 259.2 | (260) |
| | $T_2$ | 317.6 | (190) | 309.0 | (310) | 311.5 | (260) | 316.5 | (240) |
| R-.8 | $T_1$ | 282.9 | (230) | 284.5 | (230) | 290.2 | (260) | 289.0 | (270) |
| | $T_2$ | 346.0 | (260) | 339.1 | (280) | 343.0 | (290) | 355.7 | (170) |
| All | $T_1$ | 257.8 | (2200) | 259.4 | (710) | 263.1 | (1520) | 260.1 | (1530) |
| | $T_2$ | 318.4 | (1420) | 307.2 | (1660) | 309.8 | (1730) | 323.9 | (1170) |

# DISCUSSION

Generalization effects. The effect of $\pi_2$ upon simple RT in this experiment was noticeable, but somewhat equivocal. In those groups with the position of a $T_1$ fixed, the expected increase in RTs at $\pi_2 = .5$ was present, and fairly consistant across trials, but the comparatively large within group variation prevented statistical significance. Perhaps even more practice should have been given, or a covariate used to adjust for individual subject differences.

Despite the lack of statistical significance, it appears that the probability of the event on one type of trial can affect expectancies on another type trial. The question remaining concerns what is happening on $T_2$ trials, especially at $\pi_2 = .5$, that affects $T_1$ trials. Several possibilities exist, one being cue confusion. The Ss may have failed to discriminate accurately between the two cues and may have been behaving appropriately for the cue they thought it was. This is doubtful, because they had 2 sec. to make the easy discrimination of one light from two. But if they were confusing the cues, then there should have been more errors in Group F-.2 than in F-.8. In the latter group, the more frequent choice event is on the same side as the simple RT event, with 90% of the responses being made to the same side. Errors in discrimination would not affect the response made in this group. Also, Group F-.8 should be faster in responding as the Ss could be expecting to respond to this one side most of the time.

The Ss in Group F-.2 made fewer errors, overall, but their RTs were slightly faster than the Ss in Group F-.8. The Ss in the latter group may have been slowed down because of some type of response inhibition caused by the frequency of making so many responses to the same side. Results from another experiment (Massaro, Halpern & Moore, 1967) also reduce the possibility that the generalization effect was caused by cue confusion. In their study, the degree of similarity between a $T_1$ and a $T_2$ was varied. Only in the group where the Ss could accurately identify which cue occurred was the expected decrease in prediction at $\pi_2 = .5$ found, with probability matching at $\pi_2 = .2$ and .8.

Another possible explanation for the expectancies on one trial type being affected by the expectancies on the other trial type concerns the reinforcement of the Ss' expectancies. If the Ss are developing expectancies as Ss do in PL studies, i.e., probability match, then their expectancies here are reinforced least when the choice events are equiprobable. They are only correct in their predictions at a chance level, and may not be trying, or give up trying to predict the events on $T_2$ trials. In either case, their expectancies suffer, and this may cause their expectancies of the reliability of $T_1$ trials to diminish somewhat, even though $T_1$ trials are 100% reliable. Where the choice events are not equiprobable, the greater reinforcement of expectancies would cause less of a decrement, leading to faster responding on $T_1$ trials.

This explanation is a modification of the appropriate response hypothesis presented in Schnorr (1968). In the present experiment, the Ss have what might be called "appropriate expectancies" when the choice events are unequally probable. In Group F-.2, they can expect to respond to one side all of the time on $T_1$ trials, and to the other side 80% of the time on $T_2$ trials. In Group F-.8, they can expect to respond to one side 90% of the time (100% on $T_1$ trials and 80% on $T_2$ trials), and to the other side only 10% of the time, on $T_2$ trials. Therefore in these two groups, there are definite "appropriate expectancies" on both trial types. This is not true in Group F-.5, where there are no appropriate expectancies on the choice trials. This may be the cause of the decrease in expectancies on simple RT trials.

A slightly different way of looking at this possibility is to look at the group uncertainties. At $\pi_2 = .5$, the Ss have the most uncertainty as to which stimulus will occur, and response be required, on choice trials, while at the other two $\pi_2$ levels, there is much less, and equal, uncertainty. The expectancies of $T_1$, the simple RT, trials could be affected by a generalization of this uncertainty. If this is what is generalizing, then the greater uncertainty at $\pi_2 = .5$ would detract more from the Ss' certainty on the perfectly reliable $T_1$ trials than the lesser uncertainty at $\pi_2 = .2$ or $.8$. To test this hypothesis, an experiment similar to this one would have to be run with the addition of groups with $\pi_2$ values near to, but not equal to 1.0 and 0.0, so that there would be very little uncertainty on $T_2$ trials to generalize. These two additional groups would be compared with the groups with $\pi_2 = .5$. If the Ss in the minimal uncertainty groups responded faster than the groups with the intermediate $\pi_2$ values, i.e., intermediate between .5 and either 1.0 or 0.0, on $T_1$ trials, then this could be due either to uncertainty generalization or reinforcement effects. To separate the two possibilities, the probabilities could be held constant within each group, and the sequential structure manipulated as in Bertelson (1961) or Moss et. al. (1967) to give the Ss a greater chance of 'predicting' the correct response, given that the Ss can detect and use these sequential probabilities. For example, expecially at $\pi_2 = .5$, if the Ss expected that a stimulus would be repeated 75% of the time, then they could be prepared (set) for this repetition bias. But in another instance, if the sequence of trials were random (50% repetitions) then they have less chance of being prepared for a stimulus, and a lesser probability of reinforcement.

In the other three groups of the present experiment, where the cue for a simple RT trial, $T_1$, appeared randomly on either side, the results were not as expected. RTs increased as $\pi_2$ increased, instead of an inverted V-shaped function relating simple RT to the probability of the choice events. This was shown to have been caused by the overall slowness of the Ss in Group R-.8. When each of the other two groups was compared with its 'companion' group (same value of $\pi_2$) having a fixed $T_1$ position, there were no significant differences. Perhaps with different Ss in Group R-.8, the results would have looked similar to Group R-.2, and shown that the generalization effect was also present, despite the positional variability of the reliable cue.

*The repetition-alternation effect.* Simple RTs were unaffected by the events of the previous trial. Neither the repetition of the stimulus (in the same or different context) nor the repetition of the response caused any differences in RT. This would seem to indicate that the generalization effect discussed above is not due to a generalization merely from the previous trial. Rather, whatever is generalizing is more central; the trial type itself affects the Ss' expectancies, not the past trial.

When the trial of interest was a choice RT trial, though, both a repetition effect and an alternation effect were found. Alternation RTs were faster than repetition RTs when the previous trial was a simple RT trial. With the change in trial type, to a choice situation, the Ss were switching their expectancies of the relevant event. This alternation effect was expected because of the low mean and variance of run lengths, and the longer response-stimulus interval, compared to those used by Bertelson. After seeing a $T_1$ trial, the Ss tended to expect to respond to the opposite side, which is the negative recency effect noted in PL studies.

When both trials were choice RT trials, however, the Ss were faster to repeated events than to an alternation of events. So when the situation remained a choice situation, the Ss' expectancies of the response to be made did not change. This effect could not have been caused by the time interval, as the response-stimulus interval here was longer (3.5 sec.) than the longer interval (.5 sec.) at which Bertelson (1961) found no repetition effect, nor by the repetition of responses noted by Bertelson (1965), as shown by the lack of this effect when the previous trial was a $T_1$ trial. One very possible cause of this finding is the bias in the number of repetitions (1730) compared with the number of alternations (1170). This bias may have caused the Ss to develop an expectancy for repetitions, as in 4 out of the 6 groups, repetitions were almost twice as probable (1240, or 15.6%) as alternations (650, or 8.1%). In the other 2 groups, those with equally probable choice events, there was a slightly greater chance of an alternation (13.1% vs. 12.3%).

In the Bertelson (1961) study, the Ss showed a clear differentiation (48 msec.) between repetitions and alternations when repetitions were three times as prevalent as alternations. When repetitions and alternations were of equal frequency, there was no significant difference (1 msec.). Assuming, for the sake of simplicity, a linear relationship between the ratio of repetitions to alternations and the difference in RT to each, a ratio of 2:1, as noted above, would yield repetition RTs 24 msec. faster than alternations. This is only slightly greater than the differences found in the present study in those groups where repetitions were more frequent. In the two groups where there were more alternations, Groups F-.5 and R-.5, repetition RTs were not significantly different from alternation RTs. Therefore, the "repetition effect" which was found on adjacent choice RT trials seems due to the overall numerical superiority of repeated responses. Probably if the total number of alternations and repetition trials had been equal, and the inter-trial interval even longer, the "alternation effect" as found in previous studies would have occurred.

Summary. In conclusion, this study has made two points. First, psychological processes associated with a choice RT situation have been shown to affect simple RTs. Exactly which processes are involved is not known yet, although generalization is certainly one of them. This effect, originally found in probability learning experiments, implies an even closer relationship between choice RT and probability learning research. Coupled with studies showing similar effects of stimulus probability, event structure, etc., on both RT and PL, it seems that whatever these two areas are measuring, be it expectancy, information processing, stimulus sampling, or something else, it is the same underlying common denominator. Further experiments of this type may shed more light on just what psychological mechanisms are involved.

The second point concerns event structuring. This study, in addition to others, has shown that the effects of the conditional probabilities of events must be considered along with the effects of the probabilities of the isolated events. The relative speed of alternation vs. repetition responses is sensitive to both the inter-trial interval and the ratio of repeated events to alternated events. If the effects of event probabilities are to be isolated, an 'optimum' inter-trial interval and/or ratio of repetitions to alternations must be used such that speeds to repeated events would be equal to alternated events. Adjustment of the inter-trial intervals could be used where the event probabilities are far from equal.

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